Testing, Installation, Integration and Performance Studies of a Cosmic Ray Tagging System for the Short Baseline Neutrino Program Far Detector (ICARUS)

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New Perspectives
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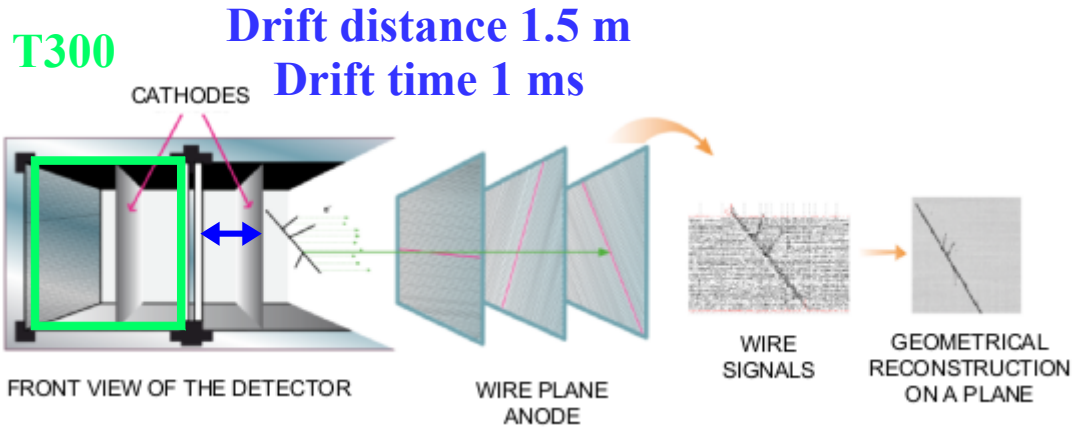
Outline

1) ICARUS past and present
2) Operating a LAr TPC on the Surface
3) Cosmogenic background mitigation
4) Cosmic ray tagger (CRT) conceptual design
5) Initial R&D at CSU
6) Top, side, and bottom CRT subsystems
7) Current Status

ICARUS Past and Present

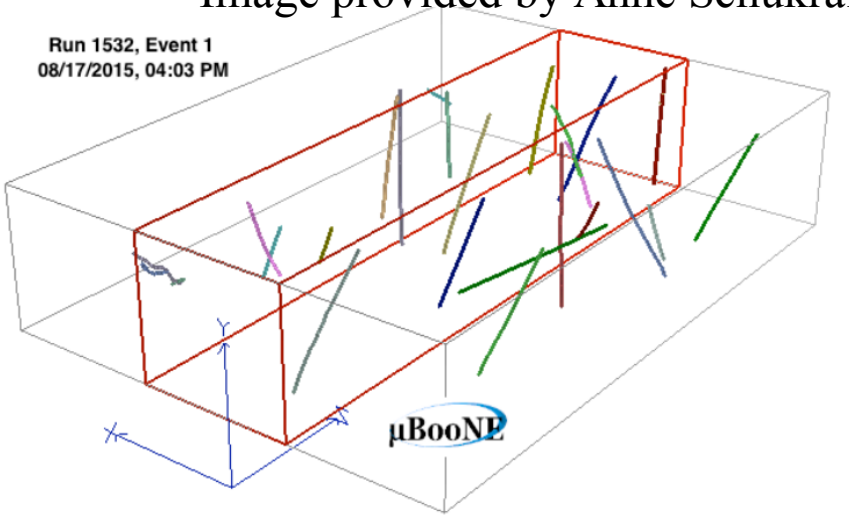
- Largest LAr TPC w/760(476 active) tons LAr
- Two 300-ton capacity cryostats w/TPC (T300s), 4 drift volumes
- Operated at LNGS for ~3 yr (below 3400 mwe)
- Made measurements on CNGS ν's and CRs
- WA104 at CERN – refurbished both modules

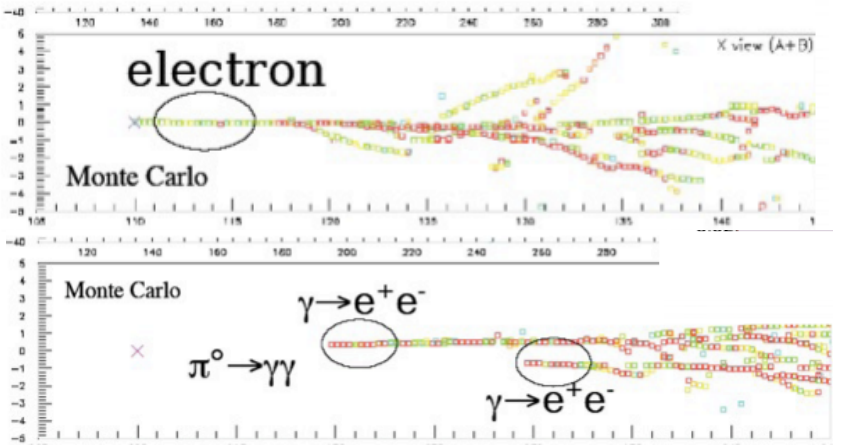


Operating a LAr TPC on the Surface

*Image provided by Anne Schukraft

- TPC positioned 9.7 m below surface w/3-m concrete overburden
- MC predicts ~12 kHz μ's passing through LAr
- ~6 μ's will pass through LAr in 1 drift time per module
- μ's passing through or near LAr can produce γ's which mimic ν_e CCQE topology



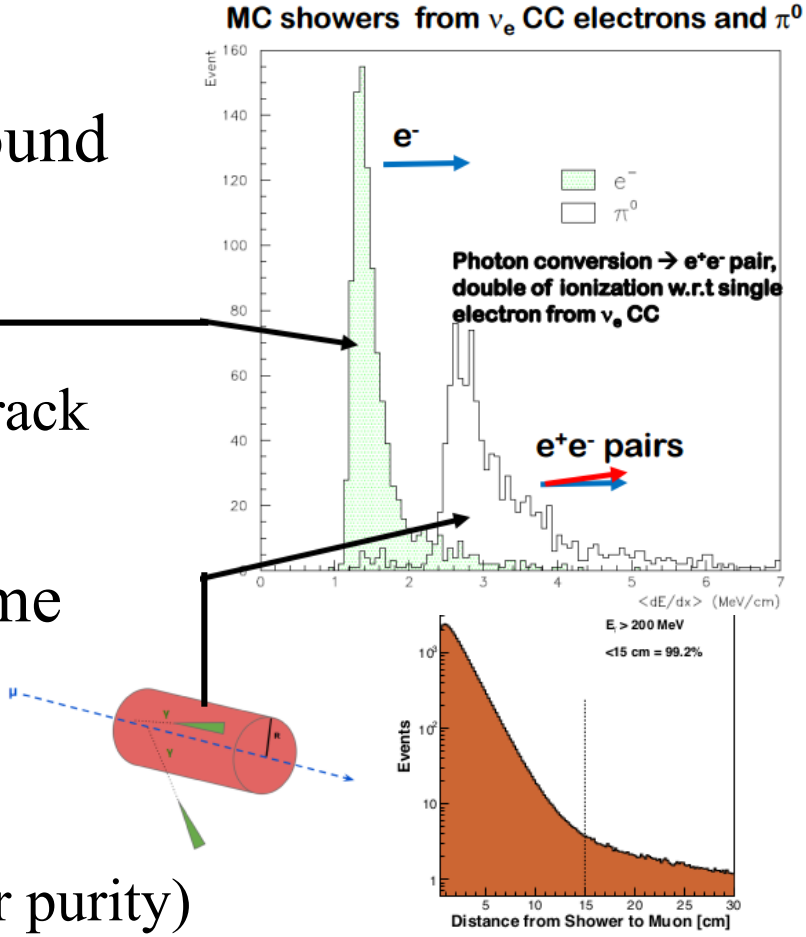


*See http://nufact09.iit.edu/wg2/wg2_antonello-microboooneargoneut.pdf

Cosmogenic Background Mitigation

*See https://indico.in2p3.fr/event/11794/session/3/contribution/44/material/slides/0.pdf

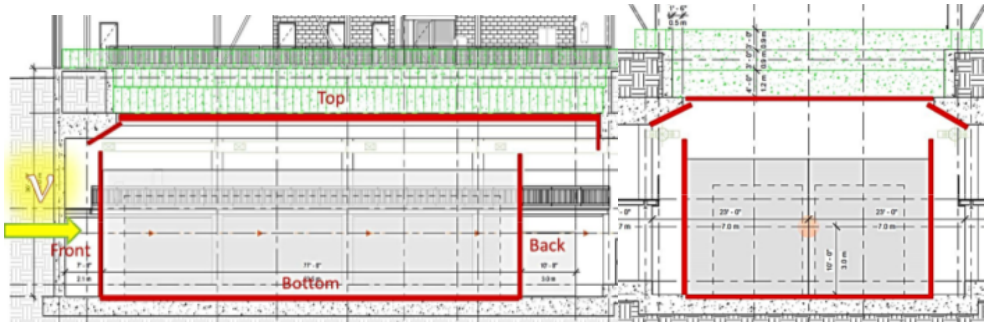
- Several methods to remove background w/TPC
  - dE/dx in initial part of shower
  - Distance of vertex candidate from μ track
  - Exploit beam spill structure
- Using tracker external to TPC volume to tag μ's
  - clean means of background rejection
  - tool for real time monitoring (e.g. LAr purity)

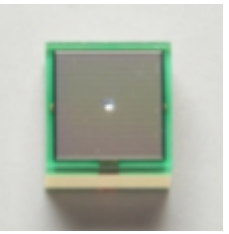


*See SBN proposal

Cosmic Ray Tagger Conceptual Design

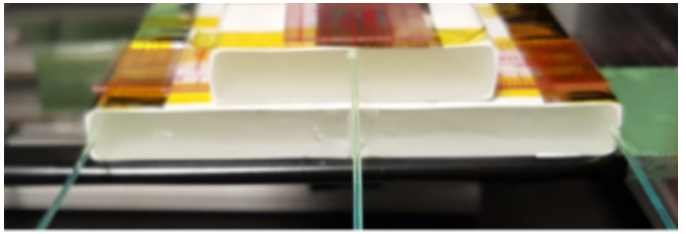
- Fully encase cryostat w/plastic scintillator (~800 m^2)
- Guide light to SiPMs w/WLS fiber
- Use dual-layer coincidence to suppress radiogenic background
- Arrange scintillator strips in X-Y configuration
- Require >95% tagging efficiency

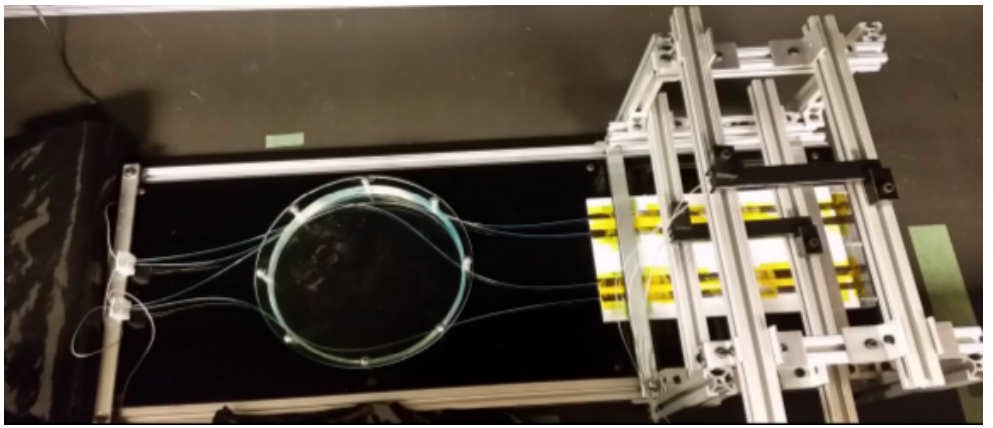


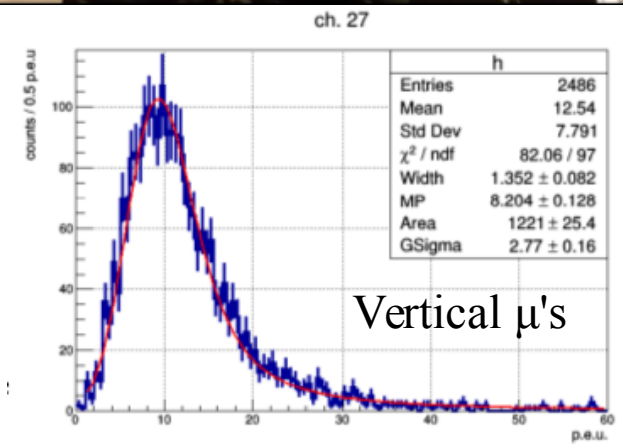


Initial R&D at CSU

- Extruded polystyrene-based scintillator from FNAL Extrusion Facility
- 5-cm strips used to build wider sections
- Used U-Bern front-end electronics for all measurements
- Tested several models of Hamamatsu and SensL SiPMs
- Many prototypes designed, built, and tested
- Measured effect of fiber diameter, attenuation length, fiber mirroring, optical coupling, fiber position, ganging...
- Final design achieved ~97% tagging efficiency at worst point



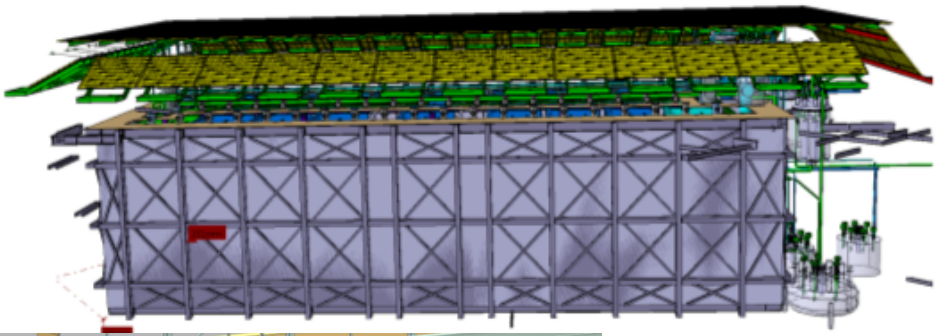


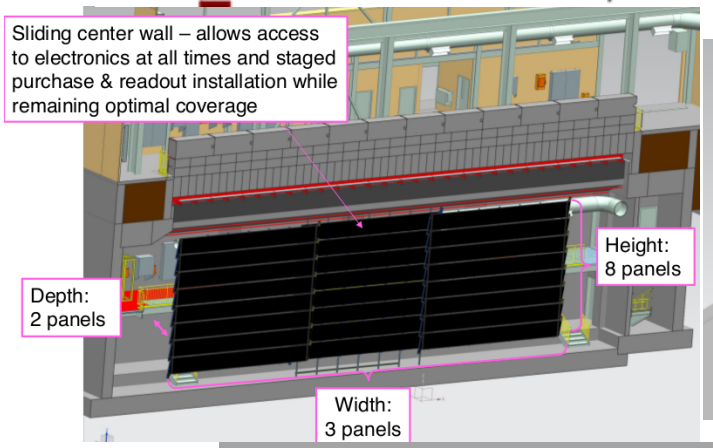


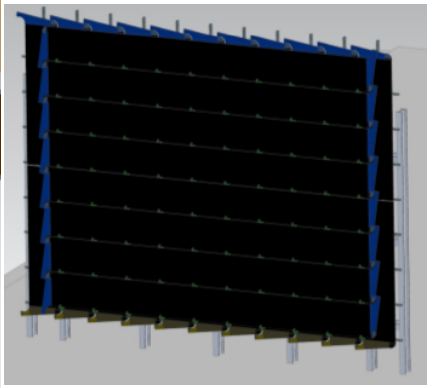
CRT Subsystems

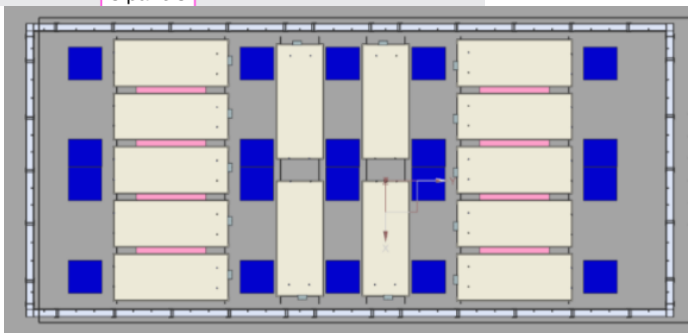
- Collaborative effort between Europe and US
  - CERN & Bologna will design and construct new modules similar to SBND design
  - Re-use of MINOS FD scintillator modules with a new SiPM based readout by FNAL and CSU
  - Re-use of Double Chooz veto modules by FNAL in collaboration with UChicago and VT
- Extra complications for DAQ, simulation and analysis
- Cost saving solution for ICARUS' large surface area

*Photo credit: Justin Tilman

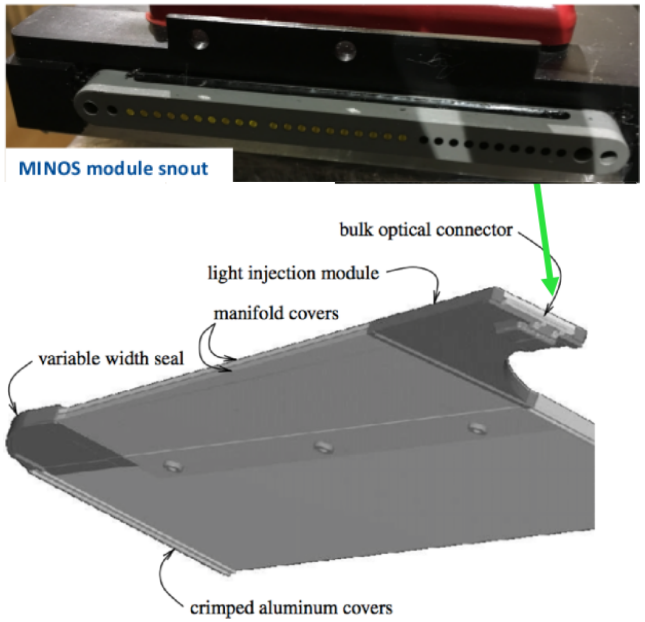


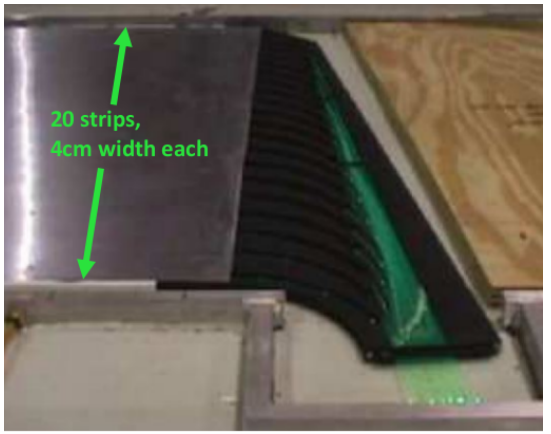


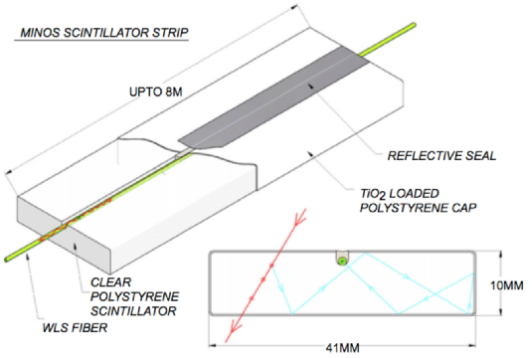




Sides: MINOS Modules



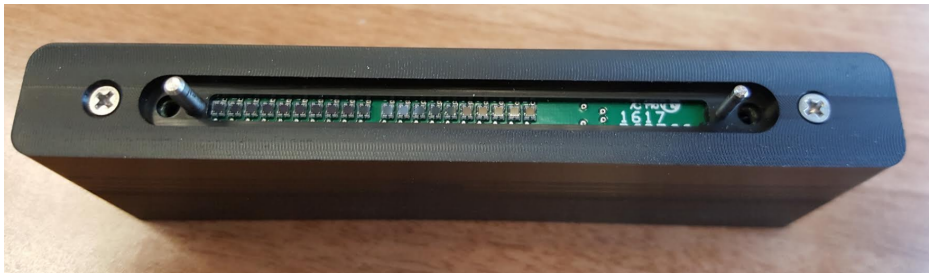


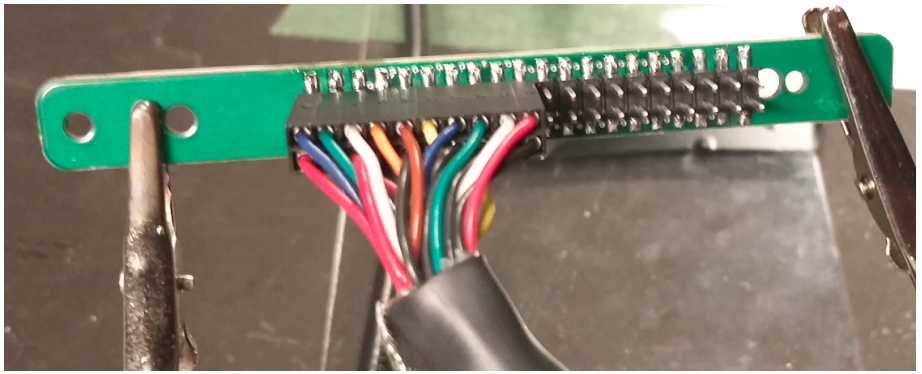


- 1cm x 80 cm x 8m
- Fibers read out at both ends
- Front-end electronics originally designed for underground CR rates (~1 Hz)
- Aging scintillator light yield loss ~2% / year

See Nuclear Instruments and Methods in Physics Research A 596 (2008) 190-228

Sides: Readout Development

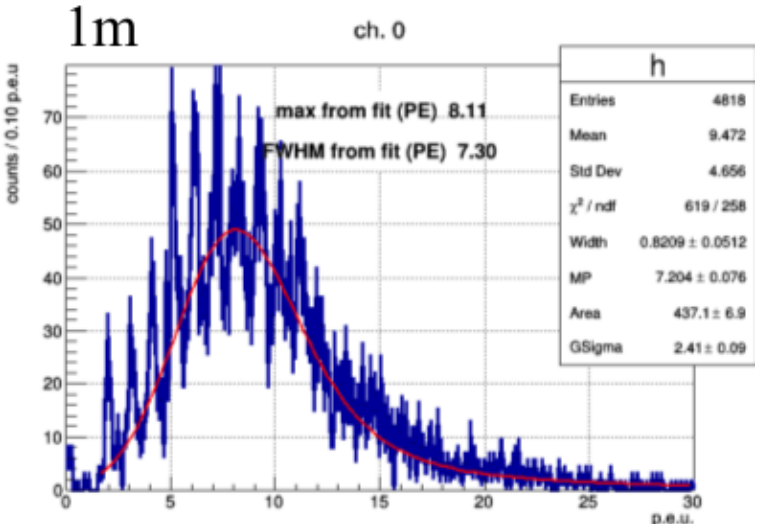




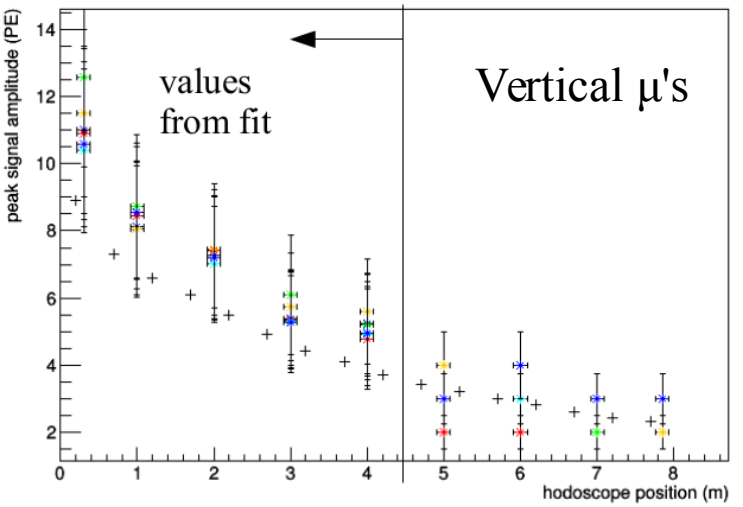
- Desirable to use same front-end electronics as top CRT system
- SiPMs offer >3x PDE w.r.t. PMTs
- Direct readout avoids interface losses
- Fiber spacing is not ideal for existing SiPM geometries
- Close-packed 1-mm^2 active area SiPMs allow single fiber readout but w/light loss (fiber diameter 1.1 mm)
- Other configurations being considered

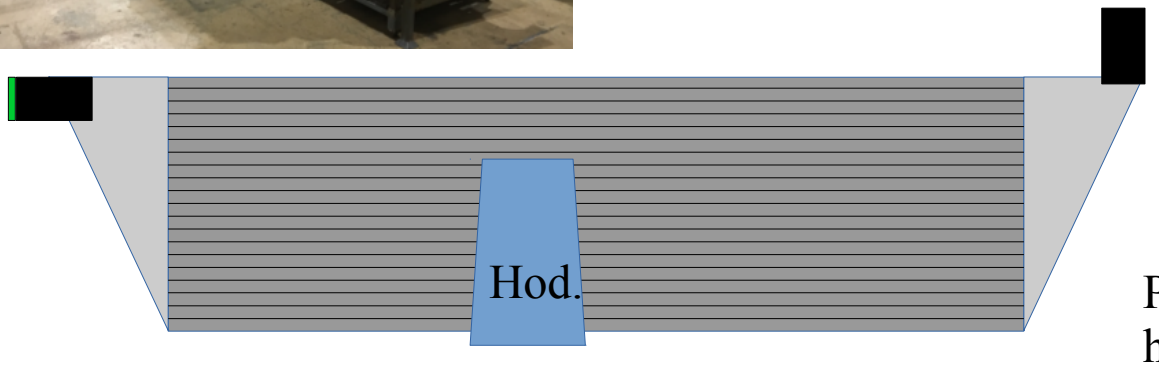
*Design and fabrication performed at CSU

Sides: Testing at Wideband



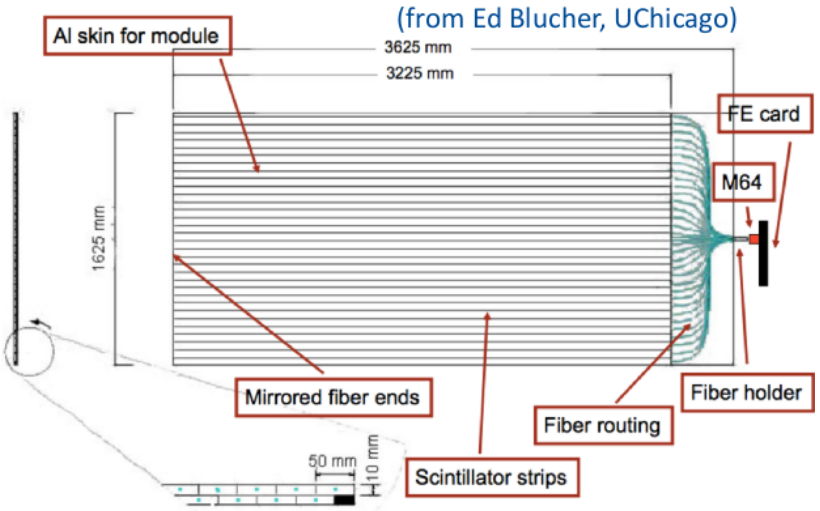
Measured Light Yield vs. Position

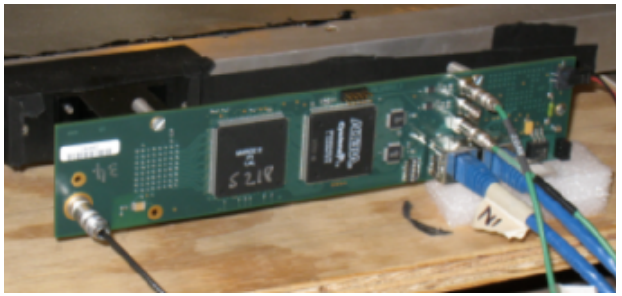


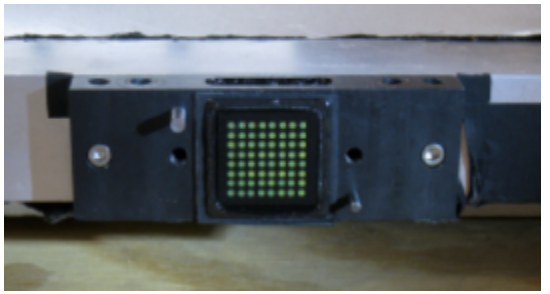


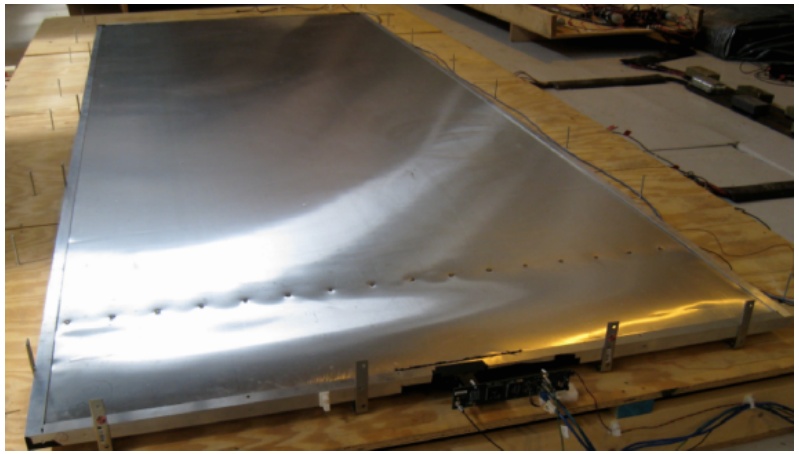
Preliminary result: yield 1-2 PE higher than MINOS result

Bottom: Double Chooz Modules









- 2cm x 1.7 m x 4m
- Single strips read out by multi-anode PMT
- Scintillator modules designed and constructed by University of Chicago
- In collaboration with Virginia Tech
- All readout electronics custom design by NEVIS/Columbia

Bottom: Installation

*Photo credit: Simone Marcocci

- 4 spare modules from Uchicago
  - Much help from V. Pandey (VT)
  - tested for light leaks
  - source tested for broken fibers
- Installation went smoothly ahead of schedule on 8 May

Current Status

- The two ICARUS T300s will be shipped from CERN in mid-June
- A summer intern team will be assisting us in testing and characterizing all 168 MINOS modules by the end of summer
- The last 10 Double Chooz modules will be tested and installed mid-June
- The mechanical support for the top and sides will be finalized this summer
- The sides readout design will be finalized by this fall

Credits

- CSU group
  - Robert J. Wilson, advisor
  - Tyler Boone, grad student
  - David Warner, sr. engineer
  - Jay Jablonski, sr. technician
  - Bob Adame, machinist
  - Blake Troksa, undergrad electrical engineer
- CERN group
  - Paola Sala, assoc. scientist
  - Umut Kose, assoc. scientist
- FNAL group
  - Anne Schukraft, assoc. scientist
  - Simone Marcocci, post doc
  - Justin Tilman, designer
  - John Bell, mech. engineer
- Virginia Tech group
  - Camillo Mariani, assoc. professor
  - Vishvas Pandey, post doc
- University of Chicago
  - Ed Blucher